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memorial to men fallen in the war. The cost of the scheme will be £150,000.

WE learn from *Nature* that Mr. D. M. Forbes, who died on December 13 last, has bequeathed to the University of Edinburgh his books relating to the Philippine Islands, and the residue of his property, which, with the property abroad, will amount, it is understood, to about £100,000, for the purposes of education.

THE council of the University of Liverpool has recently received from a donor who desires to remain anonymous a sum of money sufficient partially to endow a chair of geography. The council has felt justified, under the circumstances, in establishing the chair, and a professor will be appointed in a few weeks.

WALTER A. PATRICK, Ph.D. (Göttingen), of Syracuse University, has been appointed associate in chemistry at the Johns Hopkins University. After two years spent in physical chemical research at the Massachusetts Institute of Technology, Dr. Patrick spent a year with Freundlich, at Braunschweig, a year with Zsigmondy at Göttingen and a year as private assistant to Professor Donnan, at University College, London.

DR. HOWARD T. KARSNER, professor of pathology, has been elected secretary of the school of medicine, Western Reserve University. Dr. Russell J. Collins, demonstrator of pharmacology, has resigned because of ill health.

THE University of Cambridge will hereafter grant the degrees of master of letters and master of science for somewhat the same qualifications as the doctorate of philosophy is awarded by German and American universities. A proposal that the degree of doctor of philosophy be awarded was rejected.

## DISCUSSION AND CORRESPONDENCE

### WHEN IS A FORCE NOT A FORCE?

THE article by Mr. Gordon S. Fulcher in *SCIENCE* for November 24, 1916, calls attention in a most timely way to the vagueness which characterizes the discussion of the idea

of force in most of our modern text-books of physics, but does not make clear just how he would "use force only in the single definite sense implied in the laws of motion." Let us take the following simple case: a ball is attached to a rubber cord, say three feet in length. A person grasps the ball and pulls it with a force  $F$ , stretching the rubber cord to a length of five feet. The strain in the cord is produced by the two forces  $+F$  and  $-F$  acting at the ends of the cord. The third law of motion covers the case.

Now suppose the person swings the ball around his head at the end of the rubber cord until its velocity is great enough to stretch the cord again to a length of five feet. The stress in the cord is the same as before. The question is, what is the nature of the "reaction" which the ball is exerting on the cord to stretch it? It is certainly a "force"  $F$  (otherwise the cord would not be stretched as it is), and it is in one sense balancing the equal "action" of the cord on the revolving ball, which we know as centripetal force. Is the "centrifugal force" (inertia-reaction of the ball) in this case a force in the "single definite sense implied in the laws of motion"? Does the third law also cover this case?

We usually define force as that which produces (or tends to produce) a change in the condition of motion of a mass, either in magnitude or in direction. Certainly inertia-reaction might not come under this definition, but undoubtedly our definitions of force are intended to describe ordinary forces—mechanical, magnetic, electrical, etc.—which can do three things: (1) oppose other forces, (2) produce acceleration, and (3) produce deceleration. The force called friction can do only the first and third of these things; it can not produce acceleration (except in indirect ways). Is friction a force in good and regular standing in the "single definite sense implied in the laws of motion"?

Inertia-reaction can do only the first of these three things; it can not, by its very nature, produce either acceleration or deceleration. And yet even while it is opposing the restoring stress in the rubber cord mentioned above, we

call the force exerted by the cord, because it produces centripetal acceleration, an "unbalanced force."

What is the average student to make of it when he is told in one of our best texts that "force is exerted only while the motion is changing," and yet on the next page reads "a locomotive pulling a train with uniform velocity along a level track exerts force" on the train?

Or when in another text he is told that to every action there is *always* an equal and contrary action, and is then informed that an *unbalanced force* acting on a mass produces acceleration?

Or when he reads in one of the very best of our first-year texts that "forces always occur in pairs, one of the pair being equal and opposite to the other," and yet is told a little farther on that "by an unbalanced force we mean more push or pull in one direction than the other"?

Why can not we frankly admit that inertia-reaction acts in one respect like a force, and is actually a kind of force, even if we continue to use the term "unbalanced force" in the sense of a *force opposed only by inertia-reaction*? A porter pushing a heavily laden truck at uniform speed feels the reaction due to friction; if the friction suddenly vanished, he would feel the reaction due to the inertia of the truck. He might not know the difference, except that in the latter case he would succeed in giving the truck a small acceleration. But he would doubtless be greatly astonished to learn that in the first case his push was balanced by an equal counter-force, while in the second case his push was an "unbalanced force"!

The writer finds that the clearest (if somewhat tautological) definition of force for the average student is *that which produces motion, change of motion, compression and tension*. Under this definition the inertia-reaction of the ball revolving at the end of the rubber cord is a force, because it produces tension in the cord.

Inertia-reaction can oppose other forces, it can in that sense balance them, but it can not

hold them in equilibrium, because a force opposed only by inertia-reaction always produces acceleration, positive or negative, and may for that reason be called an unbalanced force.

If the drawbar pull of a locomotive is 1,000 pounds, and the sum of the opposing forces due to the friction of the wheels, journals, wind, etc., is 600 pounds, we may say that the unbalanced force exerted by the engine on the train is 400 pounds, and this produces acceleration. *But the pull on the drawbar is the same in both directions*—it is manifestly impossible for it to be otherwise—and the backward pull is made up of 600 pounds of frictional forces and 400 pounds of inertia-reaction.

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#### SCIENTIFIC BOOKS

*Diseases of Occupation and Vocational Hygiene*. Edited by G. M. KOBER and W. C. HANSON. P. Blakiston's Son & Company. Philadelphia, 1916. Octavo. Pp. xxi + 918. \$8.00.

Ten years ago there was no such thing as a science of industrial hygiene in the United States. During the last half of the decade Dr. Alice Hamilton, Dr. G. M. Price, Dr. E. R. Hayhurst, Mr. F. L. Hoffman and others have conducted fundamental and important investigations in this field; the American Association for Labor Legislation has organized an educational campaign which has resulted in unparalleled legislative advances; and during the past two years three good textbooks have appeared dealing with the subject—Dr. G. M. Price's "The Modern Factory," Dr. W. Gilman Thompson's "The Occupational Diseases," and the volume under discussion—besides a wealth of monographs on accident prevention and other special phases of the subject.

"Diseases of Occupation and Vocational Hygiene" is the most ambitious of these works, having been prepared under the editorship of Drs. Kober and Hanson by thirty-one American and foreign specialists in various branches. Many of the topics are so treated